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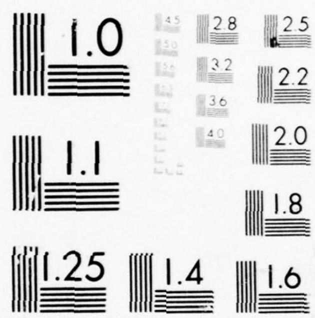
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HF AUTODIN OPERATOR'S MANUAL

Interfacing and operation of the AN/TYC-5 mobile AUTODIN terminal for use over hf radio links are described

Gerald A Clapp

Research and Development, January to August 1977

17 August 1977

Prepared for
Naval Electronic Systems Command

Approved for public release; distribution is unlimited

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The installation and operation of an AUTODIN link over a hf radio circuit are described. Descriptions are given for the interfacing of an AN/TYC-5 mobile AUTODIN terminal, a hf modem (MX-513A), and USMC hf radio equipment together with the operation of this equipment as a system capable of exchanging AUTODIN-formatted data.

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BACKGROUND

AUTODIN (Automatic Digital Information Network) is the major nontactical communications system of all the armed services. Worldwide, it monthly processes in excess of 10 million messages over a variety of wire-line, microwave, and satellite circuits. AUTODIN subscribers are serviced on terminals ranging from 75-baud teletype to 2400-baud, magnetic-tape units. Routine traffic is generally delivered anywhere worldwide within 30 minutes; higher precedence traffic even more quickly. AUTODIN is a full-duplex circuit employing ARQ (Automatic Request for Repeat) for error control. AUTODIN data are formatted into blocks of 80 characters to which parity bits and 4 control characters are added. Each transmitted block is acknowledged (ACK) on the return link if it received correctly. If the block is received in error, a NACK is sent on the return link and the data block is retransmitted.

To date the only portable/tactical AUTODIN terminal is the Mobile AUTODIN Terminal, AN/TYC-5A, constructed by Control Data Corporation for the US Marine Corps. This unit has been used successfully in Southeast Asia for 1200/2400 baud connections to AUTODIN when wire-line or good quality microwave radio links were available.

USMC operations will likely occur in areas that are not within wire-line or microwave distance of an AUTODIN access line. This document looks at facets of interfacing and operating an AUTODIN link (expected error rates of 10^{-4} to 10^{-6}) over a hf radio path where typical error rates are 10^{-2} to 10^{-4}.

DATA COMMUNICATION CONCEPTS

In order to clarify certain terms not usually used in voice communication discussions, the following definitions are given to aid readers new to the field of data communication.

DATA RATE

The data rate is the speed at which the bits are transmitted over a communications system and is expressed in terms of bits per second (bps) or baud.

DATA BLOCK

A group of bits which constitutes a basic unit for transmission is called a data block. Usually, when one or more bits in the block are in error, the entire block is rejected. The AUTODIN block consists of 84 characters or 672 bits.

THROUGHPUT

The number of data blocks which are received correctly over a set time frame, usually one minute, is called throughput. AUTODIN has an ultimate throughput of 105 blocks per minute at a data rate of 1200 bps and 290 blocks per minute at 2400 bps under 2-way, error-free transmission conditions. If data are only being transferred one way, throughputs of 107 blocks per minute at 1200 bps and 214 blocks per minute at 2400 bps are possible.

MODEM (MODULATOR/DEMODULATOR)

The modulator portion of this unit takes the digital data (combination of marks and spaces) and converts them into audio signals in order that the data may be transmitted over telephone lines or radio transmitters. The demodulator portion changes the received audio signals into digital data for processing by the terminal equipment.

DIVERSITY COMBINER

This is a device which takes two or more separately received signals (identical except for phase shifts and amplitude fluctuations) and adds them in a coherent manner such that a composite additive signal is formed which bears a stronger likeness to the original signal. Alternatively, a switch on this device may be used to select the better signal based upon information concerning signal strength or signal-to-noise ratio although, by this method, some loss relative to true diversity-combiner operation is encountered.

AUTODIN COMMUNICATION BASICS

A complete description of AUTODIN data-communication specifications may be found in DCA Circular 370-D175-1, DCS AUTODIN Interface and Control Criteria. Portions of these specifications salient to throughput discussions are included here for convenience.

DATA FORMAT

AUTODIN data blocks consist of 84 characters of 8 bits each for a total of 672 bits (see figure 1). The first character is used for determining the beginning of a message and the beginning of each subsequent data block. The second character is used for selecting the desired output device. The next 80 characters comprise the actual data. Each character is composed of 7 data bits and a parity bit (total of 8 bits) used to detect errors. Character 83 is either an end-of-block or an end-of-test character. The last character is a block-parity character used for detecting errors horizontally across the data block. The first 2 characters are not included in the calculation of block parity.

ACKNOWLEDGES

When an AUTODIN data block is received correctly at the remote receiver, it must return to the sender an acknowledge answer consisting of two 8-bit ACK characters. If a block is received incorrectly a 2-character not acknowledge (NACK) is returned. ACK1 and ACK2 character pairs are alternated to aid the continuous-mode error determination.

BLOCK-BY-BLOCK MODE

The block-by-block mode is the simplest to understand. The transmitting terminal transmits a single block and then waits for the acknowledge. If the block is not acknowledged,

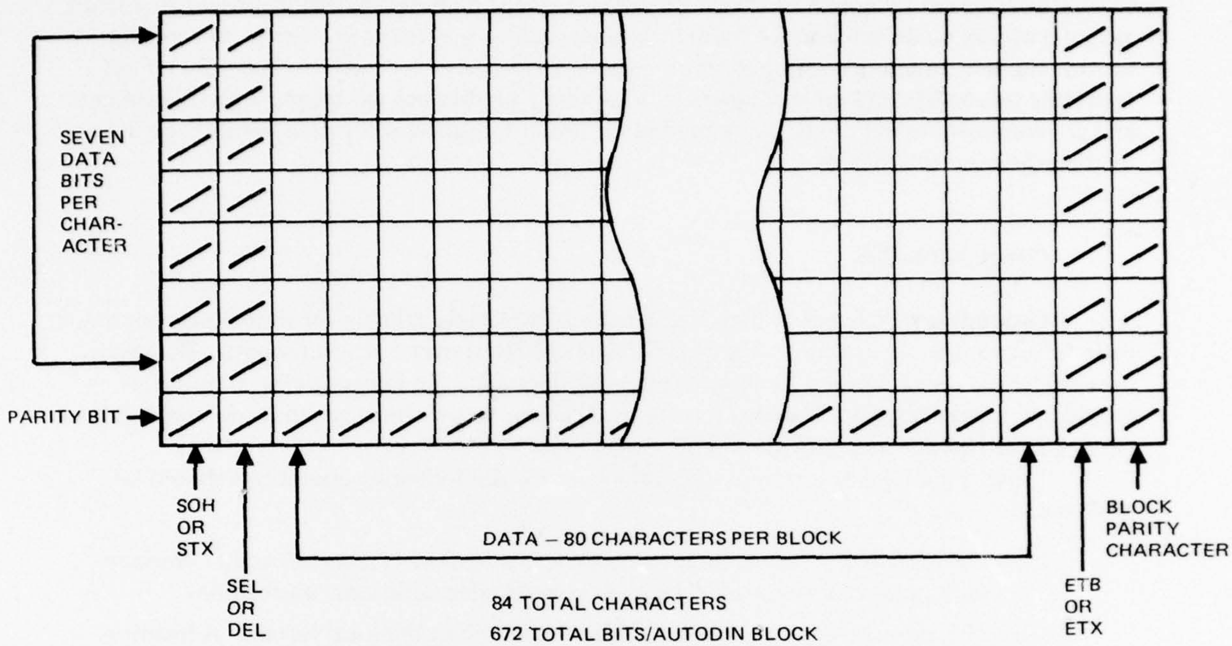


Figure 1. AUTODIN data-block format.

the transmitting terminal again transmits the block and awaits an acknowledge until the block is finally received correctly. Once a block is acknowledged, the next block in line can be transmitted.

CONTINUOUS MODE

The continuous mode is a more complicated mode than the block-by-block mode, but it has certain performance advantages. Two blocks are initially transmitted and acknowledges are accepted for each at a certain later time. If the acknowledge for the first block (ACK1) is received before the second block has been completely transmitted, the way is then clear to transmit the third block while waiting for the second block's acknowledge (ACK2), and so on, alternating ACK1 and ACK2. If a block is not acknowledged (NACK), then both the erroneous block and the block in progress of being transmitted are next transmitted. In this way, block sequencing is kept correct although the second block is transmitted twice.

HIGH-FREQUENCY BACKGROUND

High-frequency (hf) radio waves by definition are in that portion of the radio spectrum between 3 and 30 megahertz. However, since most hf radio units can operate as low as 2 megahertz, the hf range for purposes of this document will be considered to lie between 2 and 30 megahertz.

The hf band is the only frequency band capable of routine communications beyond a 200-mile (320 km) range without requiring a satellite or other signal relay point. Reliable communications at ranges up to 2000 miles (3200 km) should be achieved if proper frequency assignments are made and correct frequency management is performed. Frequency management is the selection and coordination of assigned frequencies necessary to keep the circuit operating on the best available frequency. Frequency predictions aid frequency management and are computer calculations which predict optimum frequencies for each hour of the data for the hf circuit of concern.

GROUNDWAVE

Groundwave coverage at high frequencies is extremely reliable for short-range communications. Coverage can extend to about 200 miles (320 km) over a sea-water path. However, over land, circuits are limited to about 50 miles (80 km) for the kilowatt-class transmitter. Extremely rugged terrain and dense forest or jungle can further limit groundwave communications, to the 10-to-25 mile (16-to-40 km) range.

If use is made of groundwave communications, the following conditions should be observed:

(a) Use a vertically polarized antenna such as a 32-foot (10-metre) whip. Horizontally polarized waves are subject to considerable additional absorption.

(b) The antenna should be sited as high as possible in the local terrain. A location having no nearby major obstructions between the two communications areas should be selected.

(c) *The lowest assigned frequency* (preferably between 2 and 4 megahertz) should be used since greater attenuation over a groundwave path is experienced with higher frequencies.

If these conditions are met, groundwave ranges for reliable communications should be achieved without difficulty.

SKYWAVE

Skywave propagation is the familiar mode for hf radio waves. Electromagnetic waves leaving the earth are reflected back to earth by a region of the upper atmosphere called the ionosphere. At altitudes from 70 to 280 miles (113 to 450 km), the atmosphere is electrically charged (ionized) by the ultraviolet radiation from the sun; the ionized atmosphere reflects radio waves in the hf region.

Certain high frequencies will thus propagate over long distances after one or more reflections from the ionosphere. Figure 2 shows an example of hf ionospheric propagation. At the transmitter site (range = 0 km), waves are shown leaving at elevation angles of 3 degrees and higher in 3-degree steps. The radio waves are reflected from the ionosphere at altitudes ranging from 140 km to 210 km and are returned to earth at ranges from 1250 km to 2300 km. The range from 0 to 1250 km is called the "skip" range since all of the signal has "skipped" over this range. No skywave communication is possible in this range at the frequency shown. Lowering the transmission frequency can make the skip distance as small as necessary. Raising the frequency can make skip distances as long as 4000 km.

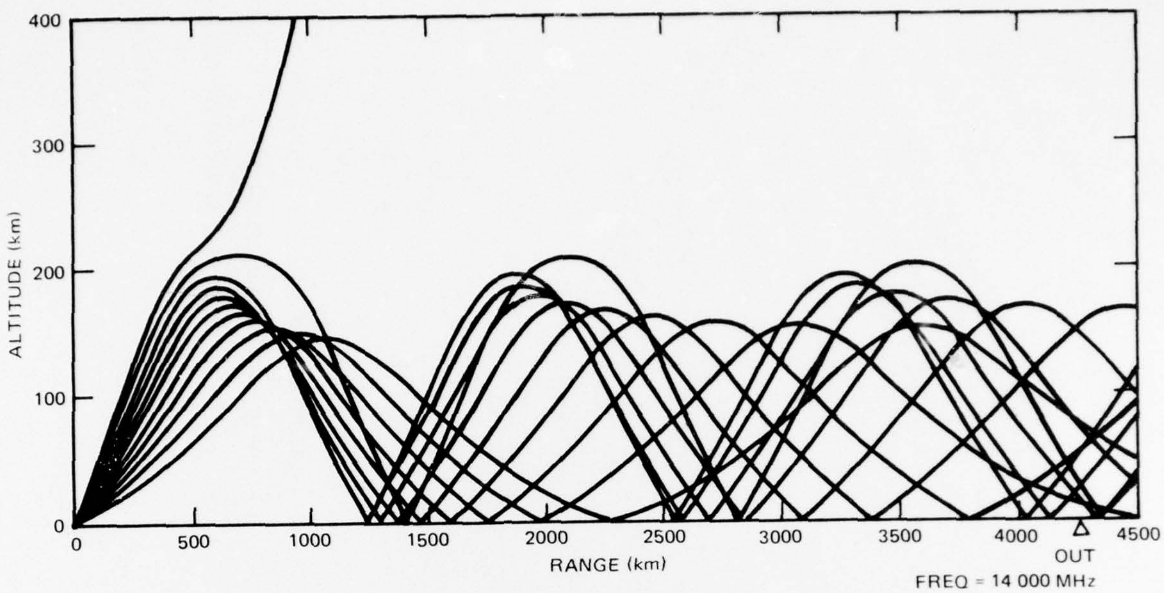
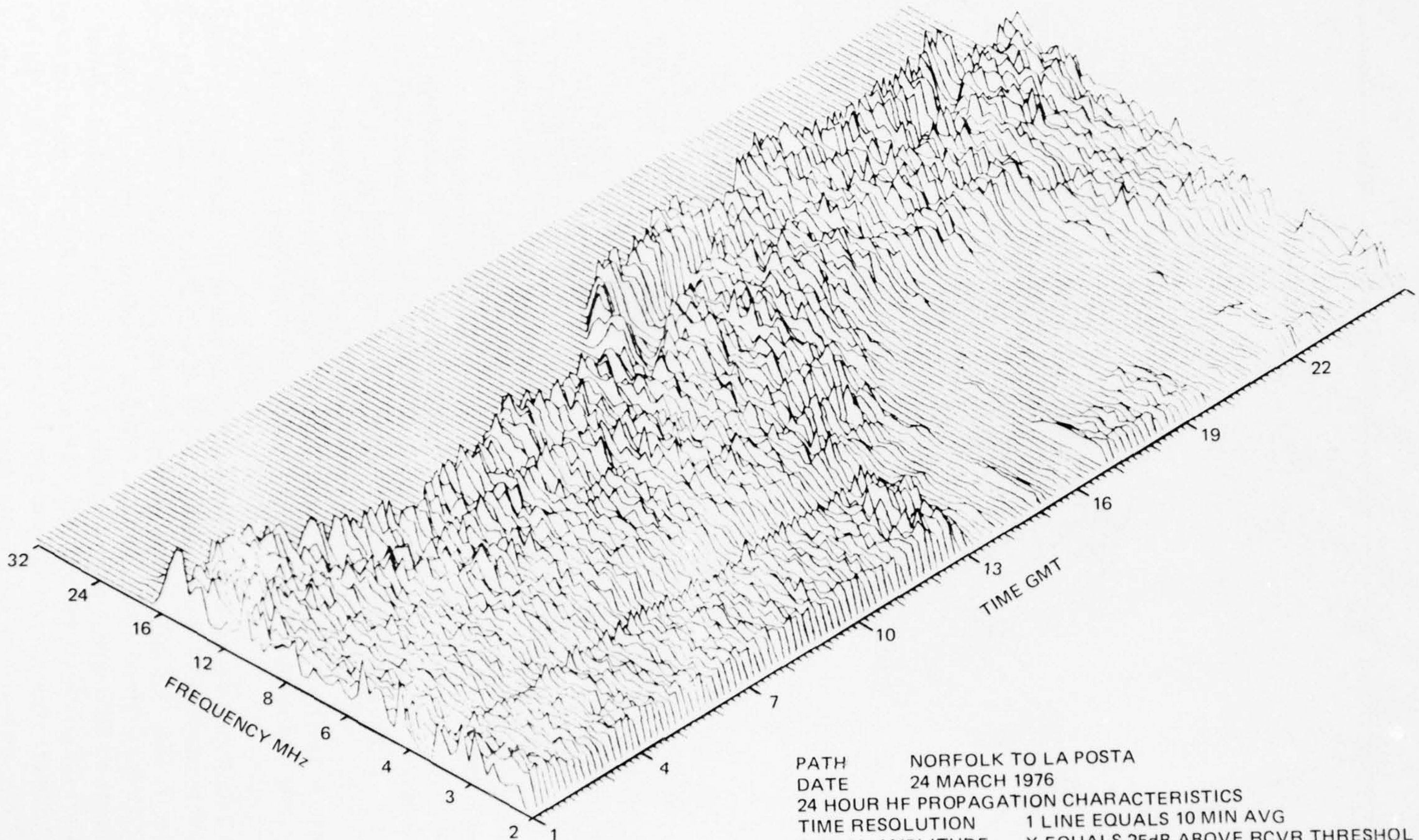


Figure 2. High-frequency ionospheric propagation.

The 1-hop coverage, as mentioned, was from 1250 to 2300 km. These waves can reflect off the earth's surface, return to the ionosphere, and again be reflected to ground. The second return to earth, in the example of figure 2, occurs at ranges from 2550 km to over 4500 km. These signals have been reflected twice by the ionosphere and, consequently, the process is called 2-hop propagation. Three-hop propagation can be seen to occur at ranges beyond 4050 km. At 4050 km and beyond, both 2-hop and 3-hop waves can be seen coming to earth at the same spots. The 2 different paths can interfere with each other, resulting in a process called *multipath interference*. The multipath interference is severe only if the two arriving signals are of nearly equal strength. Multipath interference is often characterized by substantial received signal strength but also by distortion on voice or teletype (TTY) communications. As in the case of skip distance, the multipath interference problem can be reduced by changing frequencies which will lead to changes in the relative contributions of the propagation paths.

Normal hour-by-hour propagation changes make up one of the factors which make the hf region difficult to use reliably. An excellent example of such diurnal propagation variations is shown in figure 3. Observed propagation between Norfolk and a location near San Diego (La Posta) is shown for a typical day. The data consist of 10-minute averages of received signal strength made on 80 frequencies by a sounder system. On the figure, the height of the "spikes" represents the relative signal strength. For example, at 0100 GMT, the range from 13 to 15 MHz shows the strongest signals; however, frequencies down to about 8.5 MHz are present and probably are usable by the communicator. At about 0700 GMT, the maximum



PATH NORFOLK TO LA POSTA
DATE 24 MARCH 1976
24 HOUR HF PROPAGATION CHARACTERISTICS
TIME RESOLUTION 1 LINE EQUALS 10 MIN AVG
SIGNAL AMPLITUDE X EQUALS 25dB ABOVE RCVR THRESHOL

Figure 3. Diurnal propagation between Norfolk and San Diego.

usable frequency (MUF) begins to drop and finally reaches the nighttime minimum around 1100 GMT. Note that about this time, only a small range of frequencies is being received with any amount of significant signal strength. Unless a frequency is available in the 7-to-8 MHz range, communications may be difficult at this time. At about 1500 GMT (corresponding to sunrise on the circuit between Norfolk and California) the MUF begins to increase rapidly. By 1800 GMT, the MUF is over 16 MHz and the 8-MHz transmissions are no longer present. Throughout the balance of the day, the strongest signals are found in the 18-to-22 MHz range. In figure 3, note the presence of a "valley" at about 17 MHz from 1900 to 2200 GMT. This probably represents the frequency associated with the skip area of the previous figure. Thus, depending upon the circuit, there may not always be a continuous range of usable frequencies but, rather, several ranges with gaps between them.

The general propagation characteristics exhibited in figure 3 will hold for almost any hf circuit. Depending primarily upon the circuit length, the size of the observed range of propagating frequencies and the absolute value of the frequencies will change. Figure 3 is for a path length of 2200 miles (3540 km); for longer circuits, the spread of frequencies propagating at any one time becomes smaller. For very long ranges, the spread may go to zero; no frequencies will be propagating between the 2 points at some times of the day. For shorter paths, the MUF diurnal range decreases. For example, over a 600-mile (965-km) circuit during the day, the MUF may be from 8 to 10 MHz and, at night, 3 to 4 MHz. Regardless of range, the same general day/night pattern remains. Nighttime frequencies are about 1/3 to 1/2 the value of daytime frequencies, and the MUF changes are most rapid at times near sunrise and sunset on the path.

Data from sounders and communications circuits have been accumulated for decades. From these data, the following can be concluded for an hf system with 1-kw transmitters and 32-foot (10-metre) vertical antennas over an hf circuit less than 2000 miles (3200 km) in length:

(a) The ability to communicate will be present between 98 and 99 percent of the time.

(b) Between 2 and 6 frequency changes per day will be necessary.

The high-frequency communications problem is thus seen to be frequency-management related and not propagation related. A propagation path exists nearly all of the time for a circuit 2000 miles (3200 km) or shorter. The problem is to find the spread of propagating frequencies at any given time and then to plan to ensure that the authorized frequency-assignment list covers the correct frequency range and has sufficient frequencies to cover any spread and the possibility of assigned frequencies having interference present. The HF AUTODIN link requires duplex (2 hf frequencies simultaneously) operation and, hence, is complicated by having to find 2 frequencies which meet the foregoing requirements.

HIGH-FREQUENCY COMMUNICATION TECHNIQUES

To reduce the bit-error rate, various techniques have been used which significantly improve the average signal-to-noise level and/or reduce the number and duration of fades.

SPACED-ANTENNA DIVERSITY

Spaced-antenna diversity is effective in reducing bit-error rate at hf and at microwave frequencies. At hf, the combining of output from separate antennas, through individual receivers, can be accomplished in the MX-513 data modem. Combining is done separately on each tone in the multitone package. This method is necessary because fading is often frequency selective at hf. At microwave frequencies, the fading is flat across a 3-kHz bandwidth and antenna diversity combining is done ahead of the modem by switching to the output of the antenna having the stronger signal.

At hf, it is difficult to predict quantitatively the bit-error reduction due to antenna diversity because of the variability of factors controlling channel-error rates. Experimental data taken with high-speed data modems on hf circuits show a bit-error reduction factor of about 5 for dual-antenna diversity relative to a non-diversity circuit. A space-diversity antenna system should have the 2 antennas separated as far apart as feasible, a minimum distance of about 200 feet (61 metres) being required. However, closer distances can be used, especially if the antennas have different polarizations. If 2 dipoles, long wires, or inverted-L antennas are used, they should be placed at right angles to each other to take advantage of the independent fading of polarization. The antennas should be situated such that the path direction lies between the two antenna directions.

HIGH-GAIN ANTENNA FOR HIGH FREQUENCIES

Directional antennas can be effective in reducing bit-error rate on an hf circuit in 3 ways: (1) by increasing effective radiated power in proportion to the antenna gain; (2) by emphasizing the dominant propagation mode and deemphasizing higher order modes, thus reducing multipath distortion; and (3) by suppressing off-axis noise or man-made interference.

An antenna which has power gain by virtue of a narrow beam in azimuth only, raises the effective radiated power as a transmitter and reduces interfering signals as a receiver. Such an antenna will reduce error rate only if extra sensitivity is needed to override atmospheric noise or to reject interference. When the circuit has adequate sensitivity and multipath distortion is controlling error rate, this antenna may have little effect in reducing errors. If the directional antenna has a narrow lobe in the vertical plane which can be matched to the propagation path to emphasize the dominant mode, it can be effective in reducing error rate. Multipath distortion often controls bit-error rate on circuits using modern high-speed data modems.

Since all the conditions which affect error rate are variable, it is not possible to predict with accuracy the benefit of a directional antenna. Directional antennas should be used on all hf data circuits when they are feasible and economical from the standpoint of portability when tactical deployment is required.

FREQUENCY DIVERSITY/IN-BAND DIVERSITY

Channel space can be used toward improving the quality of data transmission by duplicating the information on several different frequencies. Sideband diversity is the name given to that operation where the same information is transmitted on both upper and lower sidebands and each received sideband is separately demodulated. The MX-513 modem has

the capability of sideband/frequency-diversity combination. In-band diversity is the combination of two or more channels which are within a single sideband. The MX-513 modem uses 16 phase-shift-keyed tones to reach a data rate of 2400 baud. The modem provides the option of diversity combining the 1st and 9th, the 2nd and 10th tones, etc, to provide one order of in-band diversity. The resulting data are then 1200 baud rather than 2400. Higher orders of diversity are available, with resulting improvement in digital-data error rates and reduction in information data rates. The MX-513 can operate at 150, 300, 600, and 1200 baud with 16, 8, 4, and 2 orders of diversity, respectively.

AUTODIN CIRCUIT PLANNING

Use of HF AUTODIN requires circuit planning and coordination with various government departments. This circuit planning and coordination must be accomplished carefully and completely since the HF AUTODIN Mode 1 procedure is a new technique to the military services and the DCS. All participants must be aware of the nature of the HF AUTODIN termination so that they can contribute more fully to circuit operation. Circuit operation can proceed with greater ease if each of the watch sections at the Naval Communications Station (NAVCOMMSTA) and at the AUTODIN facility have been briefed on circuit objectives and procedures.

TELECOMMUNICATIONS SERVICE REQUEST

The Defense Communications Agency (DCA) has operational control of AUTODIN and, to obtain access to AUTODIN, a Telecommunications Service Request (TSR) must be submitted to DCA. The TSR must be submitted by a Telecommunications Certification Office/Communications Validation Office (CVO) which, for Navy and USMC requirements, is NAVTELCOMM.

The reference for this section is DCA Circular 310-130-1, Processing of Telecommunications Service Requests. DCA requires 30 days lead time if the service is in the continental US (CONUS) and 60 days if elsewhere. Thus the CVO must have any necessary information for the TSR prior to this lead-time requirement.

Close coordination between the AUTODIN user, the CVO, and DCA is essential during the formulation stage of the requirements. The efforts made at this time to develop the exact nature of the requirement can often effect significant savings in time, facilities, and money. In this stage of coordination, it should be made known that a portion of the circuit involves an hf radio link, and the hf data modems for both ends of the link are to be supplied by the USMC subscriber. The data-modem interfaces will be fully compatible with DCA AUTODIN.

The request will specify data rates and type of AUTODIN service. For the 1200/2400-baud operation using the AN/TYC-5A, AUTODIN Mode 1 is selected. Either the block-by-block or continuous mode can be selected; this selection and the choice of data rates will come from user requirements as outlined in the section of this document on circuit planning.

Other information required on the TSR includes: activation date, deactivation date, contact personnel by name and telephone number, service-point location including building number if relevant, user equipment (DCA certified Mode 1 AUTODIN Terminal, AN/TYC-5A), estimated volume of traffic, distribution of traffic, alternate subscribers (for traffic of higher precedence than authorized or for periods of outages), and security classification.

It is not necessary that any of the operation personnel be familiar with any aspect of an HF AUTODIN termination in order to file a Telecommunications Service Request (TSR). The TSR will require information provided by circuit planning. Such information comprises circuit length and location, circuit data-rate requirements, circuit availability, predictions and assignment of frequencies at hf, and antenna selection. This effort is in addition to the usual planning for obtaining radios, generators, keying materials, personnel, and the like.

CIRCUIT LENGTH AND LOCATION

The achievable performance on a circuit depends upon range and location. Short-range circuits, less than about 400 miles (640 km), suffer from multipath propagation, high nighttime noise levels, and limited spreads of propagating frequencies. Ranges greater than about 1600 miles (2600 km) begin to suffer from marginal signal strengths and, to a lesser extent, from multipath transmission and restricted spreads of propagating frequencies. Generally best propagation phenomena exist between 400 and 1600 miles (640 and 2600 km) and data-throughput rates can average higher than at other ranges. Also, higher data throughputs will occur when one end of the hf circuit utilizes the extensive hf facilities of a NAVCOMMSTA as opposed to tactical hf facilities.

These factors are considered in tables 1 and 2 which provide recommended parameters for HF AUTODIN service. Additional guidance is given in Appendix B. The appendix estimates system performance for a number of limiting cases in range, sunspot number, season, and local time of day. An estimate of performance for any case can be made by extrapolation between the values given in Appendix B. The last table in the set gives values for intermediate values of range and the like. The sunspot number as of January 1977 was 10 and it is expected to increase to 150 by 1982.

CIRCUIT DATA-RATE REQUIREMENTS

Maximum recommended data rates are given in tables 1 and 2 for operation over various ranges. Lower data rates may be selected if traffic loading is expected to be light. The hf modem, MX-513A, is capable of operation at 150, 300, 600, 1200, and 2400 baud. Operation at 150 baud is not recommended as diversity improvement over 300 baud is minimal and message-transmission times become lengthy. Operation at 300 baud should occur only when the circuit is expected to have a light load or higher priority traffic. In general, the lower data rates should only be selected when circuit availability has higher priority than data-throughput rates.

HF AUTODIN operation between 2 AN/TYC-5A units is flexible with respect to data rate. Data rates can be changed easily as traffic loading, priorities, and propagation conditions change. The duplex hf channel between the AN/TYC-5A units can make use of data rates optimized for propagation conditions on each frequency and for traffic load in each direction.

Entry into HF AUTODIN via a NAVCOMMSTA does have flexible data-rate changes. The original TSR must contain separate information for each requested data rate and a separate routing indicator will be provided for each data rate. Changing from one data rate to another will require a minimum of several hours even if properly coordinated. Thus, it is recommended that a TSR request service at only one data rate; the recommended data rate is available in table 2.

TABLE 1. REMOTE AN/TYC-5A, AN/TYC-5A LINK CIRCUIT, RECOMMENDED PARAMETERS

Path Length	Data Rate	AUTODIN Mode	Receive Antenna	Transmit Antenna	Transmit/ Receive Bandwidth
Ground Wave	2400	Continuous	Whip	Whip	3 kHz
100 to 400 miles	1200 max[1]	Block-by-block	Polarization Diversity or RLPA	RLPA	3 kHz
400 to 1600 miles	1200/2400[1]	Continuous	Sloping Vee/ RLPA or Diversity Whips	RLPA/ Sloping Vee	3 kHz
Greater than 1600 miles	1200 max[1]	Block-by-block	Sloping Vee/ RLPA or Diversity Whips	RLPA/ Sloping Vee	3 kHz

1 Lower data rates (600 baud) can be selected if estimated traffic load is light.

TABLE 2. AN/TYC-5A, NAVCOMMSTA HF LINK CIRCUIT, RECOMMENDED PARAMETERS

Path Length	Data Rate	AUTODIN Mode	COMMSTA Receive	COMMSTA Transmit Bandwidth	TYC-5A Receive	TYC-5A Transmit Antenna
Ground Wave	2400/1200	Continuous	Single Receive	3 kHz	Whip/RLPA	Whip
100 to 400 miles	1200	Block-by block[1]	Space Diversity	6 kHz[2]	RLPA or Diversity Whips	RLPA
400 to 1600 miles	2400	Block-by-block[1]	Space Diversity	6 kHz[2]	RLPA/Sloping Vee or Diversity Whips	RLPA/ Sloping Vee
Greater than 1600 miles	1200	Block-by-block[1]	Space Diversity	6 kHz[2]	RLPA/Sloping Vee or Diversity Whips	RLPA/ Sloping Vee

1 If available, use half-rate coding and select Continuous Mode.

2 Use 6 kHz for COMMSTA transmit if available, and receive in Independent Sideband (ISB) position on R-1051 Receiver. Single receive antenna only.

CIRCUIT AVAILABILITY

The number of hours per day service will be available depends largely upon frequency assignments and the ability of the operators to change frequencies to meet diurnal propagation changes. For each end of the circuit, the assigned transmit frequencies should be spread every 1 to 2 MHz throughout the spectrum.

Circuit availability can also be improved by using diversity receivers, increased transmitting power, or multiple transmitters. In-band diversity is achieved by going to lower data rates and this leads to circuit improvement with resulting higher availability. If the availability is required only a few hours per day, frequency assignments should be made in accordance with frequency predictions which yield the optimum time of day for circuit operation.

FREQUENCY PREDICTIONS AND ASSIGNMENTS

The key to success of HF AUTODIN service depends upon having a large selection of available frequencies and operators who know when and where to change frequencies. Each end of the circuit should have available transmit frequencies spaced by about 1 MHz at the low end of the hf range to about 2 MHz at the upper end of the range. This number of frequencies is about the minimum necessary to accommodate variable propagation conditions and the presence of other users on assigned frequencies. Generally, the NAVCOMMSTA will have available an extensive list of frequencies which can be made available by message request to the appropriate Navy Communications Area Master Station (CAMS). This procedure usually requires 2 days to implement. HF AUTODIN from or near a USMC base may be able to operate on assigned base frequencies. If the base assignments do not meet the recommended frequency spacings, additional frequencies should be requested. This request will be forwarded via the local CVO to the Naval Frequency Management Office (NFMO) and can take up to 60 days to process.

The range of frequencies suitable for the circuit can be predicted beforehand. High-frequency propagation predictions are routinely performed by ECAC or the Naval Ocean Systems Center (NOSC). These predictions yield maximum usable frequencies (MUF) and optimum frequencies (FOT) for each 1- or 2-hour interval throughout the day. Any request for frequency assignments should be based upon these circuit predictions: the highest predicted daytime MUF to about one-half the lowest MUF predicted at night.

The preceding discussion is applicable to 3-kHz bandwidth frequency assignments. Assignments of 6-kHz are desirable but may be difficult to come by. The 6-kHz assignment would provide flexibility to operate on either sideband as necessary to avoid interfering signals. Likewise, both sidebands in a 6-kHz assignment could be used simultaneously as a frequency-diversity pair for reception. For circuits with adequate signal levels, the 6-kHz diversity is preferred since it requires only one receiver and one receive antenna. Generally, both the 6-kHz assignment and sufficient transmit power will be available only at NAVCOMMSTAS. This is one of the recommended options in table 2. Available 6-kHz assignments from NAVCOMMSTAS are issued for NTDS use and generally can be requested on a not-to-interfere basis. Each individual use of a 6-kHz assignment must be cleared by the Navy operator through NAVCAMS.

ANTENNAS

Choice of antennas is important for optimizing performance on the HF AUTODIN circuit. The choice will depend upon circuit length, availability of antennas, and the real-estate required for installation. Tables 1 and 2 show the recommended antenna types for each circuit length. The whip is the 32-foot (9.75-metre) type typical of the AN/TSC-15 or AN/MRC-83 installation. The rotatable, log-periodic antenna (RLPA) is the Hy-Gain 1112-M and the AS-2259 is a high-takeoff-angle antenna designed for short-range circuits. Details of the Sloping-Vee antenna design are given in Appendix A.

INSTALLATION AND INTERFACES

Two types of installations are described: an AUTODIN base installation and an AN/TYC-5A remote installation. Each installation is capable of exchanging data with its own or other types of installation.

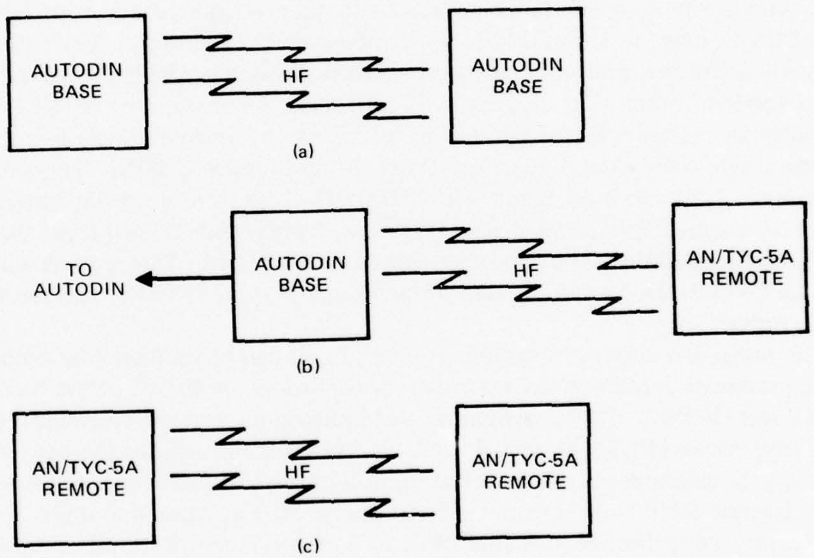


Figure 4. Installation types.

The AUTODIN base station is no more than an hf facility which has direct access to a dedicated Mode 1 AUTODIN line. For USMC terminations, the base station is likely to be a NAVCOMMSTA which has a leased line into the nearest AUTODIN switching center. The base station could alternatively be a USMC hf facility with AUTODIN line access. The AN/TYC-5A remote station consists of the AN/TYC-5A mobile AUTODIN terminal, the MX-513 hf modem, and associated hf radio equipment. The radio equipment used successfully to pass the high-speed digital data from has been the AN/TSC-15 with separate R-1051 receivers or the AN/TSC-95 which contains three R-1051 receivers and two AN/URT-23 transmitters.

REMOTE AN/TYC-5A INSTALLATION

The basic block diagram for the tactical AN/TYC-5A installation is shown in figure 5. The actual physical layout depends upon the individual installation and the availability of space. The hf modem, MX-513A, can be located wherever space is available; in previous tests it has been located in the AN/TYC-5A van, in the radio van, or in an auxiliary van. It is most convenient, but not necessary, to locate the hf receivers and the modem at the same location.

The modem clock provides timing for both the entire receive and transmit portions of the system. The transmit clock (from the modem) determines the rate at which digital data is clocked out of the AN/TYC-5A and into the modem for transmission. The digital-data stream going into the modem is then phase-shift modulated onto 16 audio tones. The 16-tone package is sent to the hf transmitter for transmission on one or both sidebands of an assigned hf frequency.

On reception, the system functions as follows: the voice-band audio output from the hf receiver(s) is sent to the modem. Two receivers may be used to provide diversity improvement as illustrated in figure 5. The audio signal to the modem is again 16 audio tones, each spaced 110 Hz. The modem demodulates the audio and produces the digital-data stream at the appropriate data rate. Receive timing and clock are determined by the modem based upon the received data pattern. The clock and data are then passed to the AN/TYC-5A where the data are outputted. The clock rate, as established by the modem, is used to determine the timing of the TYC-5A and its crypto.

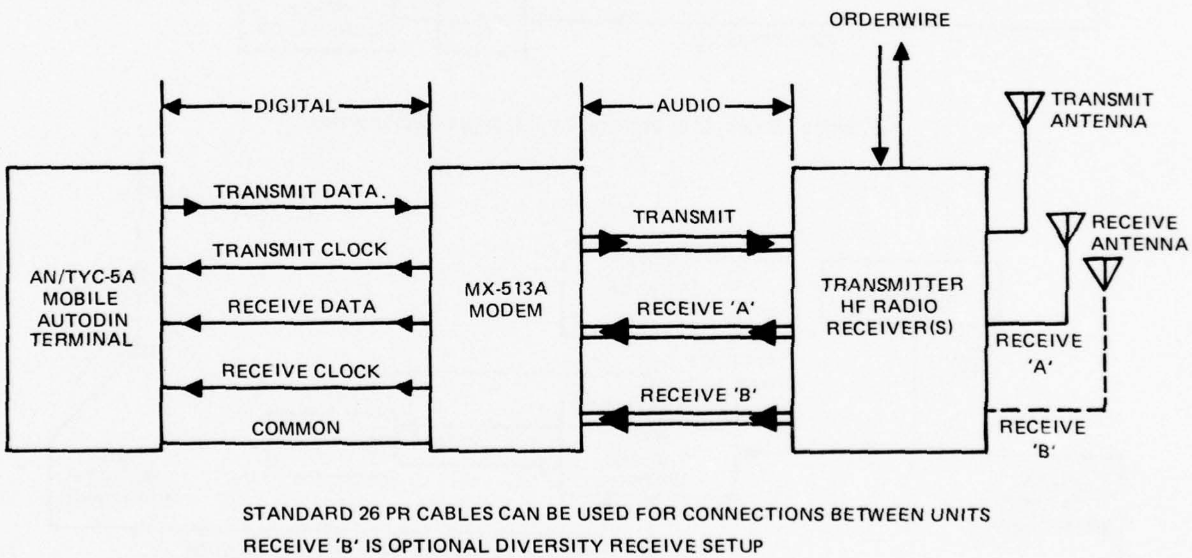


Figure 5. Tactical location, equipment block diagram.

PHYSICAL LAYOUT

The layout between the various vans, generators, and antennas will depend upon available space. Two layouts which have been successfully used are shown in figures 6 and 7. The layout in figure 7 is for the case of diversity receivers and antennas and the layout of figure 6 depicts the case of a single receiver and antenna. The single most important requirement for layout is to maximize the physical separation between the transmit and receive

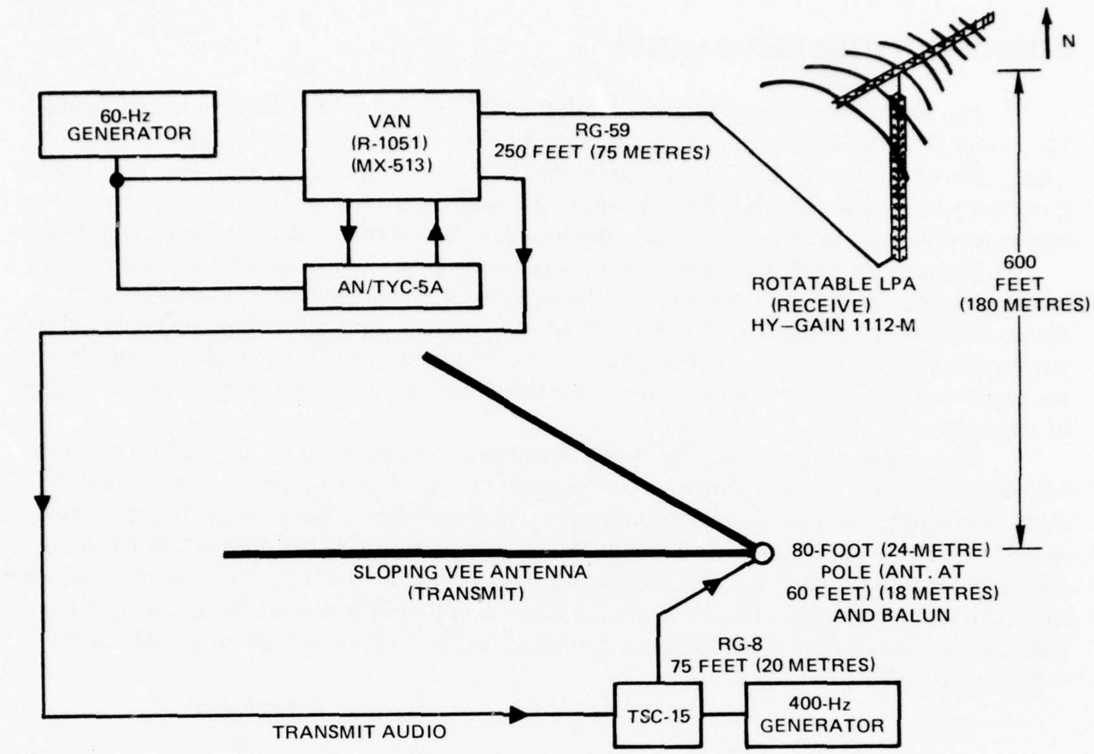


Figure 6. Example of physical layout, single receive system.

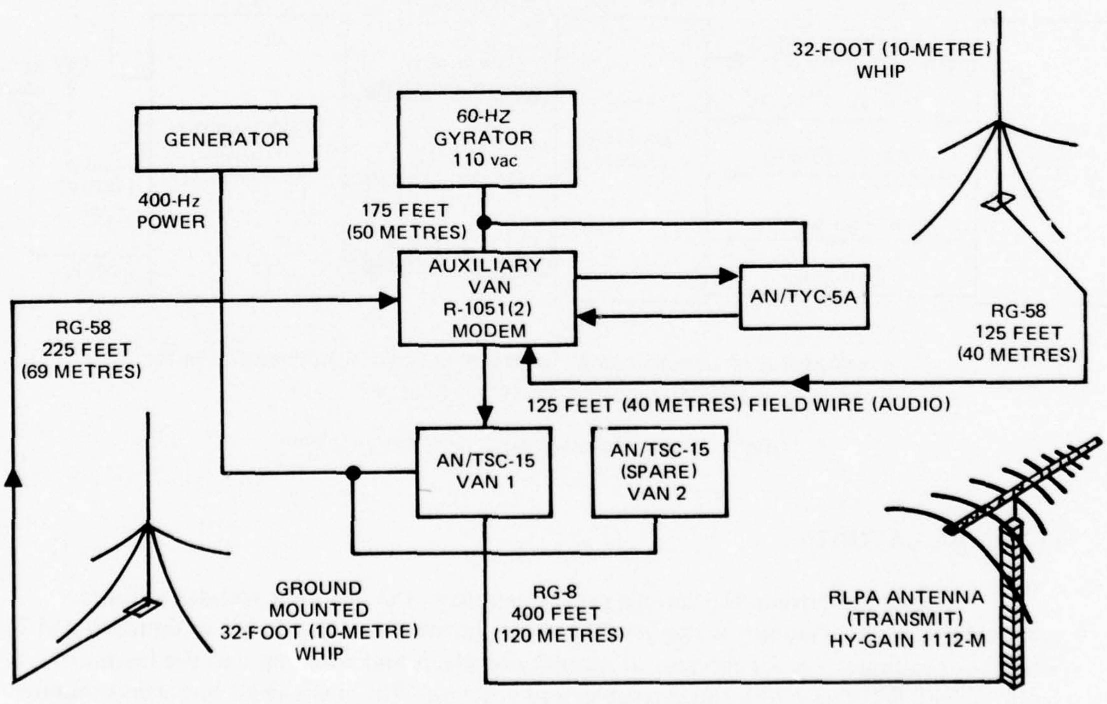


Figure 7. Example of physical layout, diversity receive system.

antennas. Separation of 200 feet (61 metres) should be considered minimum and 400 to 500 feet (120 to 150 metres) is desirable for reducing local interference between the transmit and receive. Also to be taken into account are transmission losses which can amount to about 1 dB per 100 feet (30 metres) of cable. Thus, space permitting, the layout of figure 6 is preferred where a long transmit audio line is used to reach the transmitter which is located at nearly the base of the transmit antenna. The receive antennas are then placed in the opposite direction of the equipment vans for a total separation of about 600 feet (180 metres). The antennas shown in figure 6 are not necessarily the ones required. The transmit antenna could alternatively be the 1112-M RLPA or even possibly the roof-mounted vertical of the AN/TSC-15. Likewise the receive antennas could be a RLPA or a Sloping-Vee. If the 32-foot (9.75-metre) whips are used, it is recommended that they be used as a diversity pair along with two R-1051 receivers, and separated by a minimum distance of 200 feet (60 metres). Details of Sloping-Vee antenna construction are given in Appendix A.

INTERFACE OF AN/TYC-5A TO THE MX-513A MODEM

Clock and data digital signals must be passed between the AN/TYC-5A and the MX-513A hf modem. Table 3 gives the connections that must be made.

TABLE 3. CLOCK AND DIGITAL CONNECTIONS

Function	Modem Connection	AN/TYC-5A Connection (at the CAU)
Transmit Clock	As marked on cable provided	TB8–Pin 14
Transmit Data	As marked on cable provided	TB8–Pin 16
Receive Clock	As marked on cable provided	TB8–Pin 17
Receive Data	As marked on cable provided	TB8–Pin 18
Common/Ground	As marked on cable provided	TB8–Pin 13

In addition, the synch inhibit in the CAU must be accomplished. This is performed by placing a connection between A1 – J11 and A1 – J8. If the digital modem cable is not provided, the pin connections for the digital data on connector J1 are as follows:

Transmit Clock	Pin 9
Transmit Data	Pin 1
Receive Clock	Pin 33
Common/Ground	Pins 2, 4, 6, and 8
Receive Data	Pin 25

Other necessary pin connections are the –6 volts on pin 42 to be jumpered to pin 52. This insures that the modem will operate in the data-transmit mode and not in the continuous preamble mode. Also the modem transmit clock is not internally connected; the connection must be supplied by placing a jumper between pins 9 and 17.

This procedure removes the MD-701 modem internal to the AN/TYC-5A and replaces it with the externally-supplied MX-513A hf modem. The clocking and timing of the AN/TYC-5A which was provided by the wireline modem are now provided by the MX-513A. For the AUTODIN application of the MX-513A, the modem transmitter will be on continuously. The Push-to-Talk (PTT) feature of the modem is not required and, to put the modem in continuous transmit, a jumper is placed between pins 41 and 43 on connector J1. This connection must be made before the unit can transmit data and may already be provided in the cable supplied or may be provided as a toggle switch attached to the cable.

The AN/TYC-5A and the MX-513A digital input and output levels are MIL-STD-188C low-level, bipolar, ±6 volts.

It is recommended that the digital-data leads between the AN/TYC-5A and the modem be kept as short as possible to avoid rf and ac pickup.

INTERFACE OF MX-513A TO RADIO EQUIPMENT

Audio inputs and outputs of the MX-513A modem are 600 ohms. The audio output level is adjustable between −22 dBm and +2 dBm, and it should be adjusted to provide the proper input to the transmitter. The receiver accepts audio input levels from −33 dBm to +7 dBm. Optimum modem performance is obtained when the average audio input to the modem is adjusted in the range −5 dBm to 0 dBm.

RECEIVER ADJUSTMENTS

The audio output levels of the R-1051 receivers are easily adjusted to provide the nominal input level between −5 to 0 dBm required by the MX-513A modem. On the R-1051B receiver, the level is adjusted by the meter and the line-level control on the front panel. On the R-1051D receiver, the audio-output adjustment requires that the front panel be opened and the level adjusted by a screwdriver on the control just behind the front panel.

TRANSMITTER ADJUSTMENTS

Because of adjustments and aging of the various hf transmitters that may be used, the audio input level to the transmitter to drive it to the proper power output must be adjusted in each application. For the AN/TRC-75/TSC-15, the power output must be adjusted so that it does not exceed 300 watts. For the AN/URT-23 transmitter in the AN/TRC-95, the power output should not exceed 500 to 600 watts. Power outputs beyond these levels will lead to excessive clipping of the signal and resultant increase in the digital bit-error rate. For transmitters without automatic load controls or constant-level amplifiers, the audio input must be adjusted until the desired rf power output is obtained. The transmit audio level coming from the modem to the transmitter is adjusted at the modem. This adjustment is made by unscrewing the front panel of the MX-513 modem and locating circuit card A2, which is the second card from the right. At the rear of circuit card A2 are 2 small adjustable potentiometers, one for each of the modem's audio output circuits. Adjust the potentiometer with a small screwdriver until the desired transmit power is achieved. The modem is adjustable between + 2 dBm and −22 dBm; the AN/URT-23 will probably require −13 dBm, which is about mid-range of the adjustment.

AN/TSC-15 TRANSMIT

VOX amplifiers and constant-level amplifiers can be bypassed by inserting the signal at the operator's jackfield rather than at the exterior connections of the AN/TSC-15. Receive and transmit audios are available on the 4th row of jacks; USB XMIT and LSB XMIT are on J15 and J17, respectively. USB receive and LSB receive are on J16 and J18, respectively. Input/output levels on these jacks are –1 to –4 dBm if the unit is performing properly. Impedances off the jackfield are 600 ohms and match the MX-513A modem.

If the AN/TSC-15 external audio ports are used, make certain the transmitter is not driven beyond an output power of about 300 watts. If overdriving is observed, adjustments to the constant-level amplifiers will have to be made. There are 4 such amplifiers, units 3A13A7 through 3A13A10, all located on the console accessory panel unit 3A13A. Adjustable gain controls provide the means of adjusting the output of these amplifiers until the proper transmit level is obtained.

BASE STATION INSTALLATION

Two candidate configurations exist for the AUTODIN base station. The first places the installation and operation of the hf modem at a NAVCOMMSTA. This is illustrated in figure 8. The second configuration puts the modem under control of the AUTODIN technical controller at the AUTODIN Switching Center (ASC). This configuration is shown in figure 9.

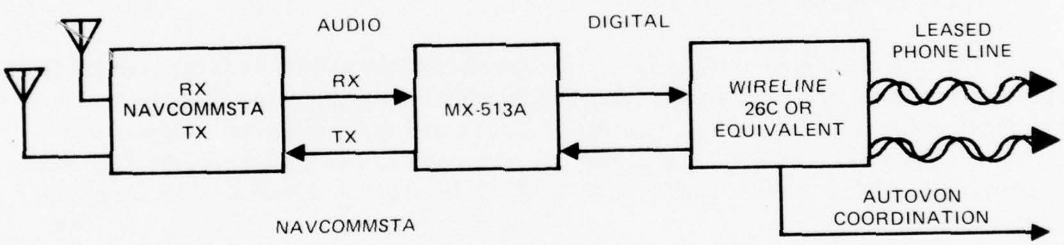


Figure 8. Base station configuration (NAVCOMMSTA)

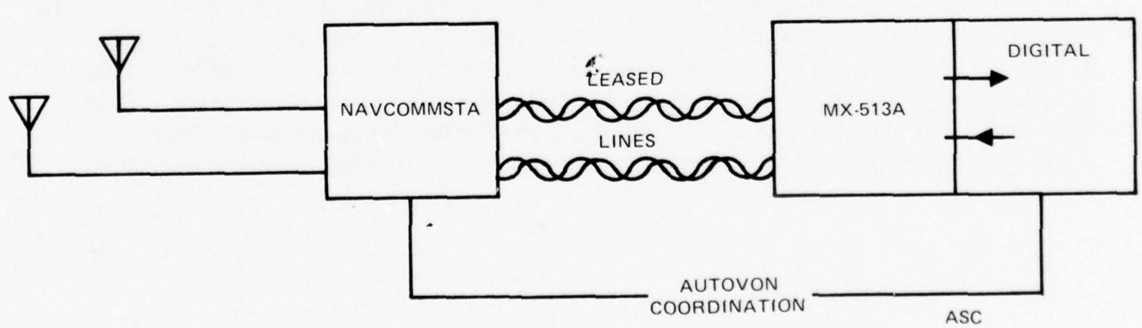


Figure 9. Base station configuration (ASC)

Figure 8 shows the hf modem MX-513A located at the NAVCOMMSTA. For test purposes, the NAVCOMMSTA location was preferable because both transmit and receive radio circuits could be monitored and adjusted directly. The disadvantage of a NAVCOMMSTA location is that the system requires an additional modem for data transmission over the line from the NAVCOMMSTA to the ASC. The wire-line modem used in the test period was the MD-701 (Lenkurt 26C) and was supplied as part of the Telecommunications Service Request (TSR). NAVCOMMSTA personnel are not familiar with either the MD-701 or the MX-513A. Operationally, the second situation shown in figure 9 appears to be preferable. The modem is located with the tech controllers at the AUTODIN Switching Center. No additional wire-line modems or wire-line interfaces are required. This preferred layout for HF AUTODIN may not hold true if future versions of the hf modem contain orderwire TTY capabilities. The operational procedure for either of the installations is given in CIRCUIT OPERATION AND CHECKOUT.

A third possible alternative exists, although the circuit is yet to be tested. The connection is to the Naval Comm Processing and Routing System (NAVCOMPARS) colocated at a NAVCOMMSTA. This arrangement would not require submission of a TSR, nor provisions for leased lines or wire-line modems, and would require only minimal coordination for the entry. Details of an AUTODIN NAVCOMPARS hf entry technique and test will hopefully be available soon.

PHYSICAL LAYOUT OF AUTODIN BASE STATION

NAVCOMMSTA LOCATION

The main requirement for a specific location in a NAVCOMMSTA is the availability of the audio lines from the transmit and receive radio sites and for the phone lines to the AUTODIN Switching Center. Space for the hf modem and the wire-line modem is also required. Generally, the required space and the audio lines will be available in the Technical Control facility of the NAVCOMMSTA. The OIC of the area will designate a site for equipment installation.

AUTODIN SWITCHING CENTER LOCATION

Space availability for the modem installation, and security clearances for access to the AUTODIN Technical Control facility should be arranged before the anticipated operation. If both are not obtained, the modem will have to be located outside the complex and the necessary digital and audio lines must be obtained. Audio line levels are generally −13 dBm in the ASC area; the optimum modem input is 0 to −5 dBm. Spare line amplifiers are installed and can be patched into the circuit easily by request to bring the signal up to the required level.

BASE STATION INTERCONNECTION OF UNITS

NAVAL COMMUNICATIONS STATION

The audio signal from the hf receiver site will be available at a patch panel with a level of −13 dBm. It is recommended that a line-level amplifier be used to bring the signal level up to about −5 dBm to 0 dBm. The line amplifier can generally be patched into the circuit in a matter of minutes by NAVCOMMSTA personnel.

The modem will come with an audio cable wired for two receive lines and two transmit lines. The modem will also come supplied with a second cable for the digital-data signals. The marked wires on this cable will be for the wire-line modem supplied under contract as a result of the Telecommunications Service Request (TSR). This wire-line modem should have cable connections marked for Receive Data, Receive Clock, Transmit Data, Transmit Clock, and a Common Ground. These wires can then be connected directly to those from the digital data cable. Figure 10 shows the interconnection between the wire-line and hf modems.

The 2 original MX-513A modems acquired by the USMC require modification before they can be used in conjunction with a direct AUTODIN termination. The modification should have been made before delivery of the modem. The modification involves transmit timing and clocking; generally, the hf modem will provide timing for a data communications system. However, the AUTODIN system standard timing must be used; thus, the transmit timing must come from AUTODIN rather than from the hf modem. The required modification

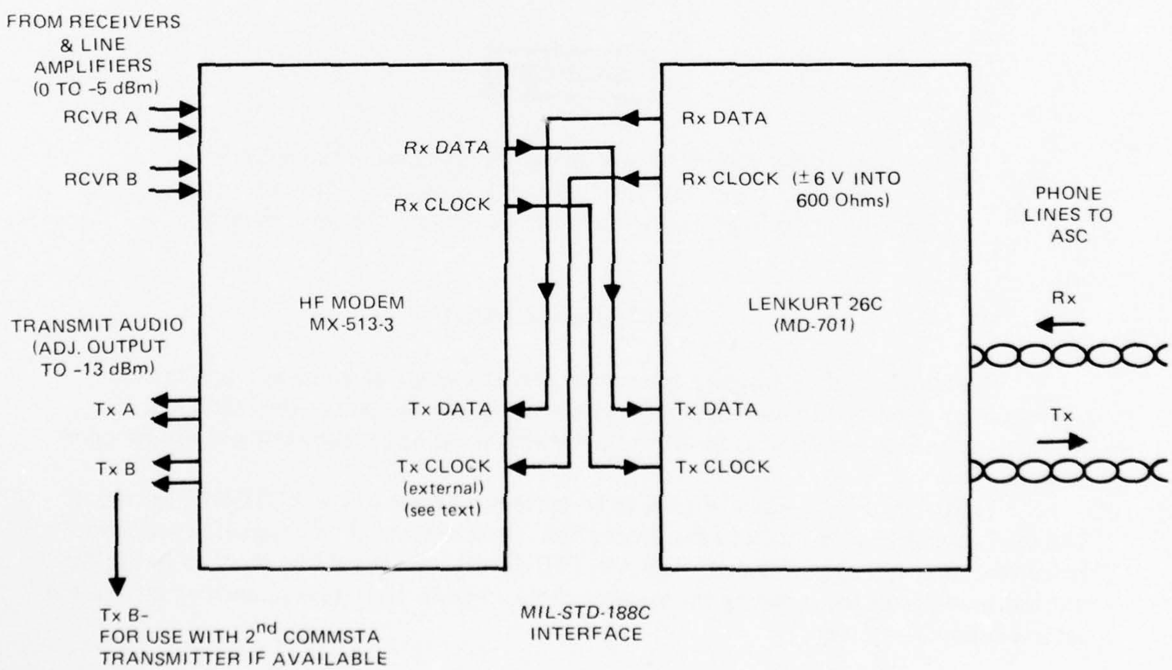


Figure 10. HF modem and wire-line modem NAVCOMMSTA installation.

permits the modem to derive its timing from AUTODIN and bypasses the internal clock and data buffer in the modem. It was found that the 2 clocks differed by sufficiently large amounts such that bit integrity was often lost. The internal wiring changes are:

Card A2, Pin A19 to Card A14, Pin A29 (wire added, backplane)

Card A2, Pin A15 to Card A13, Pin B10 (wire added, backplane)

Card A2, Pin A15 to Card A2, Pin A27 (wire removed, backplane)

Card A2, connection to Pin 4 of IC U4 (removed)

AUTODIN SWITCHING CENTER

Then the modem is located at an ASC, the unit connections will be much like the NAVCOMMSTA installation except that the wire-line modems, Lenkurt MD-701, will not be required. The AUTODIN transmit clock and data will go directly to the transmit data lines of the MX-513 modem and the modem receive data and clock will go directly to the AUTODIN receive digital-data lines. As in the case of the NAVCOMMSTA installation, the modem must have the timing modification. ASC installations usually include the wire-line modem and, thus, a reminder to installation personnel may be required to bypass the wire-line modem since the supplied modem, MX-513A, will be providing digital data at the correct interface values.

Audio interfaces are the same as in other installations; incoming phone-line signals are generally at a –13 dBm level whereas the optimum modem performance occurs at input levels of 0 to –5 dBm. If possible, station personnel should be requested to patch a line amplifier into the receive audio circuit of the MX-513A modem.

CAUTION

Ensure that a good electrical ground is provided to the modem and to all units and test equipment attached to it. Ground-loop pickup at 50 to 60 Hz can damage the digital-data input circuitry.

CIRCUIT CHECKOUT

The methods of performing equipment checkout, system checkout, and system operation are described in this section. Preliminary to any operation, the individual equipments and their interfaces to other equipments must be checked out and proper operation verified.

Table 4 outlines a series of tests to be performed prior to HF AUTODIN operation. The tests should be performed in the order given, since each must be completed successfully before the next can be performed. The AN/TYC-5 operation should be checked out in the self-test mode prior to beginning the systems check in table 4. Details of each of the tests in table 4 follow the table.

TABLE 4. CHECKOUT TESTS

Test	Purpose	Operate Mode Switch Position
1. MX-513 Modem loopback	Check modem operation in all modes	Loopback 2
2. Loopback through TYC-5 and MX-513 modem	Confirms correct interfaces between modem and TYC-5	Loopback 1
3. Loopback through TYC-5, MX-513 modem, and hf radio equipments	Confirms proper operation of radio equipment and interfaces to radio	Operate
4. Loopback with above over hf path to NAVCOMMSTA a. Audio loopback at remote end	Confirms performance with hf circuits included, including an evaluation of the hf frequencies selected	Operate
b. Digital loopback with hf modem at remote end	Checks second modem operation	

MODEM OPERATION

Operation of the MX-513A modem necessary to perform system checkout and operation will now be discussed. Additional information on the model is available in the technical manual, "Operation and Maintenance Instructions, Digital Data Modem MX-513A," Publication Number 2740-3018-1, General Atronics Corporation, March 1976. The following is a discussion of the functions of the various controls and indicators on the front panel of the modem as shown in figure 11.

POWER ON/OFF

This control is a combination indicator, circuit breaker, and ON/OFF switch.

POWER SUPPLIES INDICATORS

This group consists of 8 light indicators, one for each voltage used in the model. When power is applied to the unit, all these indicators must light. If they do not, a power supply problem is indicated.

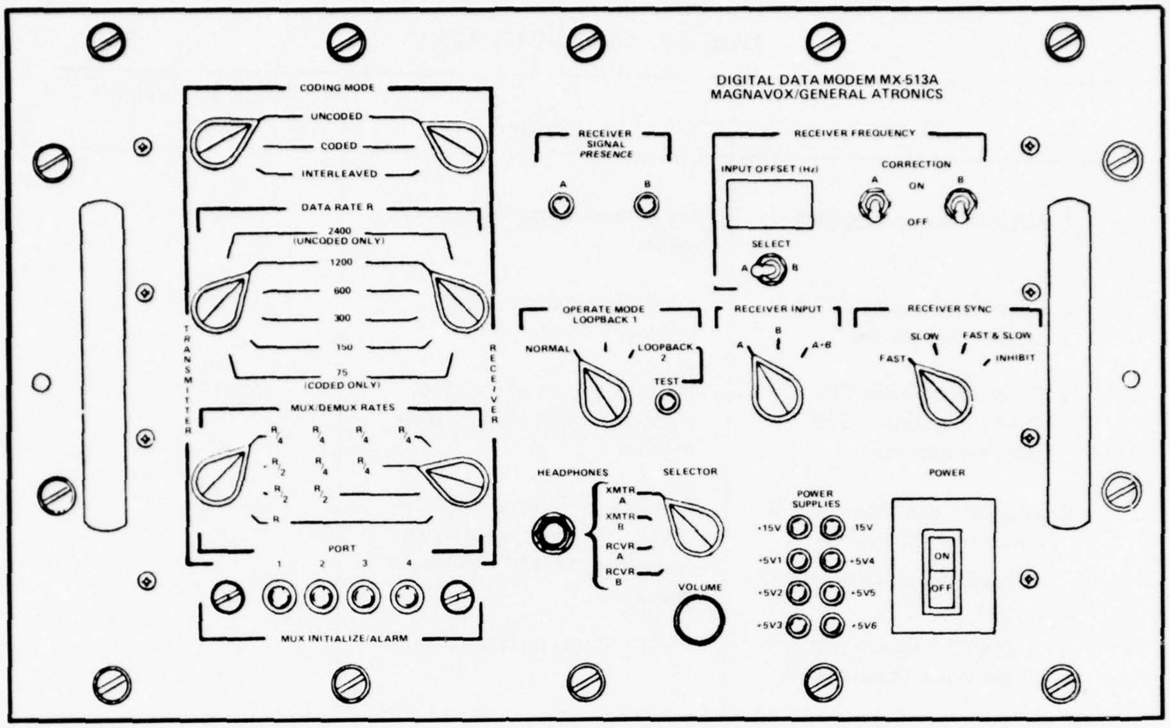


Figure 11. Controls and indicators.

OPERATE MODE

This is a rotary-switch control having the following positions:

NORMAL which connects the modem for normal operation;

LOOPBACK 1 which connects the transmitter audio output to the receiver audio input, permitting operation of the modem via the local digital equipment. In this mode, the audio lines are disconnected from the rear-panel analog connector;

LOOPBACK 2 which connects the modem for self-testing. The same back-to-back audio connection as in LOOPBACK 1 is made. In addition, a 15-bit random sequence is applied to port 1 (only) and the received data are checked for errors. The LOOPBACK 2 test indicator indicates successful execution of the LOOPBACK 2 test. If this light should go dark during the test, a problem is indicated. Should the light go dark, repeat the test several times only after allowing the switch to remain in the LOOPBACK 1 position for several seconds.

RECEIVER SIGNAL PRESENCE INDICATORS A AND B

These lights indicate the presence of a valid DPSK signal at the receiver inputs.

CORRECTION A

This control enables or disables the receiver frequency corrector for receiver A.

CORRECTION B

This control enables or disables the receiver frequency corrector for receiver B.

INPUT OFFSET

This is a 2-digit and sign display which shows the amount of frequency offset on the incoming signals. It can show plus or minus offsets up to 79 hertz.

SELECT

This is a 2-position toggle switch which selects the display of the A receiver frequency offset or the B receiver frequency error.

RECEIVER INPUT

This is a 3-position rotary switch which, in position "A", connects both modem receiver input channels to the receiver A audio output, in position "B", connects both modem receiver input channels to the receiver B audio output, and in position "A + B", connects the A and B channels of the modem to their respective inputs.

RECEIVER SYNC

This is a 4-position rotary switch with the following positions: FAST (not used for AUTODIN operation), SLOW which allows only the slot synchronization to operate (the receiver time base is corrected by 12.5 microseconds each frame with the correction distributed over the frame; switch must be in SLOW position for AUTODIN operation), FAST AND SLOW (not used for AUTODIN operation), INHIBIT which permits neither fast nor slow synchronization. This mode is useful in the prevention of sync jamming when the modem is used with an ultra stable 100 kHz reference.

CODING MODE SELECTORS

These selectors consist of 2 rotary 3-position switches, one for the transmitter and one for the receiver. Each has positions UNCODED (for normal AUTODIN data), CODED (not connected), and INTERLEAVED (not connected).

DATA-RATE R SELECTORS

These are a pair of rotary switches used to independently select the data rates for the transmitter and receiver. Data rates of 150, 300, 600, 1200, and 2400 baud can be selected.

MUX/DEMUX RATE SELECTORS

These are a pair of rotary switches used to independently select the rate at which input port will accept data to the transmitter and the rate at which each receiver will output data from the 4 output ports. Both switches are placed at "R" for AUTODIN use.

MUX INITIALIZE/ALARM INDICATORS

These indicators are not connected and any display should be disregarded.

HEADPHONES

This is a jack for connecting headphones or a loudspeaker to monitor the input or output tones of the modem; impedance is 8 ohms.

SELECTOR

This is a 4-position rotary switch used in conjunction with the headphones jack to choose which of the 2 receiver inputs or which of the 2 transmitter outputs will be monitored.

VOLUME

This is a rotary control for adjusting the volume of the headphones or speaker.

TEST AND CHECKOUT PROCEDURE

The purpose of this test is to determine if the modem is operating correctly. Place the power switch to the ON position and observe if the 8 power-supply indicators are lighted. If any one of the 8 indicators fails to light, a fault in the power supply is indicated and reference should be made to the modem technical manual.

Allow a few minutes for the modem to warm up and stabilize. While waiting, set controls as shown in table 5.

TABLE 5. MODEM CONTROL SETTINGS

Control	Setting
CODING MODE	UNCODED (Transmitter and Receiver)
DATA RATE R	2400 (Transmitter and Receiver)
MUX/DEMUX RATE	R (Transmitter and Receiver)
OPERATE MODE	NORMAL
RECEIVER INPUT	A + B
RECEIVER SYNC	SLOW
RECEIVER FREQUENCY CORRECTION A & B	ON

Momentarily place the OPERATE MODE switch in the LOOPBACK 1 position and then to the LOOPBACK 2 position. Note that a short (1 or 2 seconds) pause may be required when switching from LOOPBACK 1 to LOOPBACK 2 to allow the receiver to synchronize with the transmitter.

In the LOOPBACK 2 position, the modem is disconnected from the radio set and from the local digital equipment. Internal test circuits generate and monitor test data. For as long as the modem is in the LOOPBACK 2 mode, both signal presence indicators and the LOOPBACK 2 test indicator should be lighted. If any indicator fails to remain lighted, a problem is indicated and the self-test should be repeated after setting both data-rate switches to 1200.

TEST 1 – MX-513 MODEM CHECKOUT

Purpose: Determines if modem is operating correctly

1-1 TURN-ON Operate power switch to the ON position and observe that the eight power supply indicators come on immediately. If any one does not, a fault of the power supply is indicated and refer to modem technical manual.

1-2 WARM-UP Allow a few minutes for the modem to warm up and stabilize before proceeding. While waiting, preset the controls as follows:

a. TRANSMITTER and RECEIVER

(1) CODING mode to UNCODED
(2) DATA RATE R to 2400
(3) MUX/DEMUX RATES to R

b. OPERATE MODE to NORMAL

c. RECEIVER INPUT to A + B

d. RECEIVER SYNC to SLOW

e. RECEIVER FREQUENCY CORRECTION A&B to ON

1-3 MODEM SELF-TEST Place the OPERATE MODE switch briefly in the LOOPBACK 1 position and then switch to the LOOPBACK 2 position.

Note that a short (1- or 2-second) pause may be required when switching from LOOPBACK 1 to LOOPBACK 2 to allow the receiver to synchronize to the transmitter. In the LOOPBACK 2 position, the modem is disconnected from the radio set and from the local digital equipment. Internal test circuits generate and monitor test data. As long as the modem is in this mode, both signal presence indicators and the LOOPBACK 2 test light should be lit.

TEST 2 – LOOPBACK THROUGH TYC-5 AND MX-513 MODEM

Purpose: Establishes correct interfaces to TYC-5 from MX-513

Establishes correct operation of TYC-5

1-1 PRELIMINARY Complete Test 1 that determines that MX-513 modem is performing correctly.

1-2 TYC-5 Self-test of the TYC-5 to insure that unit can loopback message traffic to itself.

1-3 Set the MX-513 modem controls as in Test 1:

a. TRANSMITTER and RECEIVER

(1) CODING mode to UNCODED

(2) DATA RATE R to 2400

(3) MUX/DEMUX RATES to R

b. OPERATE MODE to NORMAL

c. RECEIVER INPUT TO A+B

d. RECEIVER SYNC to SLOW

e. RECEIVER FREQUENCY CORRECTION A&B to ON

1-4 MODEM & TYC-5 LOOPBACK SELF-TEST

Set the OPERATE MODE switch to position LOOPBACK 1. In this mode, the modem is disconnected from the radio set and the local TYC-5 is used to generate and monitor test data. TYC-5 generated digital signals input to the modem transmitter are looped-back through the modem and appear as digital data at the modem receiver output. The signal presence lights should be on and steady.

1-5 TEST – At this point the TYC-5 should be able to loop messages back to itself through the modem without errors or block rejections.

TEST 3 – LOOPBACK THROUGH TYC-5, MODEM, AND HF RADIO

Purpose: Determines if local hf radio receiver and transmitter are capable of passing AUTODIN digital data.

1-1 PRELIMINARY – Completion of TESTS 1 and 2 successfully.

1-2 MODEM CONTROLS – Set the modem controls as in table 5.

a. TRANSMITTER and RECEIVER

(1) CODING mode to UNCODED

(2) DATA RATE R to 2400

(3) MUX/DEMUX RATES to R

b. OPERATE MODE to NORMAL

c. RECEIVER INPUT to A+B

d. RECEIVER SYNC to SLOW

e. RECEIVER FREQUENCY CORRECTION A and B to ON

1-3 HF RADIO CONTROLS – The local hf receiver(s) will be used to receive the locally transmitted signal.

a. Place transmitter and receiver(s) on same frequency.

b. Adjust transmitter for minimum transmit power. For TRC-75/TSC-15 place power switch in LOW. Key the transmitter on.

c. Receivers. Tune R-1051 receivers and put in same mode as transmitter, USB, LSB, or ISB. USB is preferred mode of operation. For the R-1051B place the AGC position in SLOW. Adjust the audio output of the receiver to read between –5 dBm and 0 dBm when a signal is being received. For the R-1051B the audio level adjustment is on the front panel; for the R-1051D the adjustment requires opening the front panel of the receiver. R-1051D has no switch for AGC position.

1-4 LOOPBACK TEST – The TYC-5, the modem receiver signal presence lights, the modem input offset display, and the headphones will all be used to determine performance of the local equipment.

a. If only one receiver is being used, insure that this receiver is connected to audio input A on the modem. Place the RECEIVER INPUT switch to A, and the RECEIVER FREQUENCY SELECT switch to A. If a correct signal is being received, the receiver SIGNAL PRESENCE lights will both be on steady. Off lights or blinking lights indicate a problem; most likely problems are over-driven transmitter, overloaded receiver, or frequency offset between transmitter and receiver. If a problem is indicated, see test step 1-4 d.

b. If both SIGNAL PRESENCE lights are on and remain on without flashing, loopback a message from the TYC-5 to determine that the local equipment is functioning correctly.

c. Check the INPUT OFFSET display. If the hf transmitters and receivers are properly calibrated, the OFFSET display should read 3 Hz or less. If the display is 3 Hz or less, switch the CORRECTION A switch to OFF and ascertain that the SIGNAL PRESENCE lights remain on.

d. Troubleshooting. Failure of the loopback through the hf radios can likely be corrected by readjustments. If a problem is indicated, the first step is to monitor the data signals using headphones. Place the HEADPHONES SELECTOR switch in XMTR A and listen to the transmitted signal as it sounds when leaving the modem. The receive signal from the R-1051, as received locally, should sound identical and can be heard by placing the HEADPHONES SELECTOR in RCVR A or RCVR B depending on which receiver is being used. If no signal is heard, then there is a transmitter keying or frequency problem, or a receive frequency not tuned properly.

Other problems are:

(1) Overloaded receiver. The signal is heard in the headphones but is distorted. Disconnect antenna and listen; if the problem was receiver overload, the signal now should sound "clean" and the SIGNAL PRESENCE lights should come on steady.

(2) Overdriven transmitter. It may be necessary to lower the audio output of the modem to keep from overdriving the hf transmitter. Overdriving will result in distortion and clipping of the signal. To adjust the audio output, open the modem cabinet by releasing the thumbscrews and find circuit card A2. The card has two small variable resistors, one for transmitter A (XMTR A) and one for transmit channel B. Adjust variable resistor while watching SIGNAL PRESENCE light and monitoring headphones. Adjust audio output for maximum value before the occurrence of distortion.

(3) Frequency offset between transmitter and receiver. The frequency corrector in the modem will correct for offset up to 75 Hz when the CORRECTION switch is ON. If the offset is greater than this value, the INPUT OFFSET display will be blank or flashing random numbers and the SIGNAL PRESENCE lights will be off or blinking. If frequency offset is suspected, listen to the transmit and receive signal in the headphones; if a difference in tone is obvious, a frequency correction must be made. Correct by adjusting the frequency of the R-1051. The outer ring of the CPS switch in the upper left corner is placed in the V (VERNIER) position. With the CPS switch at the VERNIER position, the VERNIER control

may be used to vary the operating frequency from 0 to 1000 Hz above the operating frequency selected with the MCS and KCS controls on the receiver. The VERNIER is adjusted to cause the INPUT OFFSET display on the modem to read 0 Hz, at which time the SIGNAL PRESENCE lights should be on steady and the TYC-5 should be able to loop data through the local system.

e. Second receiver. When a second receiver is used for diversity, reception procedures a. through d. should be repeated. Place the RECEIVER INPUT switch to B and the SELECT switch to B and repeat a, b, c, and d.

f. Diversity performance. When two receivers are used, check the local diversity performance by placing the RECEIVER INPUT switch to A+B. Both SIGNAL PRESENCE lights should remain on. Correct diversity performance can be checked by off-tuning one of the receivers, noting that its SIGNAL PRESENCE light goes off, and verifying that TYC-5 data can still be passed through the radios and modem.

g. The in-band diversity combining can be checked by placing the TRANSMITTER and RECEIVER DATA RATE R to 1200 and repeating step a.

TEST 4 – LOOPBACK OVER RF CIRCUIT

Purpose: Confirms performance of hf radios at both ends of circuit.

Checks performance of modems at both ends of circuit.

Evaluates the duplex hf frequencies selected.

1-1 PRELIMINARY – Successful completion of TEST 3.

1-2 MODEM CONTROLS – Set the modem controls as follows:

a. TRANSMITTER and RECEIVER
   (1) CODING mode to UNCODED
   (2) DATA RATE to 1200
   (3) MUX/DEMUX RATES TO R

b. OPERATE MODE to NORMAL

c. RECEIVER INPUT to A+B if two receivers are used; to A if only one receiver is being used and is connected to A input.

d. RECEIVER SYNC to SLOW

e. RECEIVER FREQUENCY CORRECTION A & B to ON

1-3 HF CIRCUIT – Establish a duplex hf link between the two communications points. Have the remote end of the link patch their receive signal back to their transmitter and retransmit the signal back on the return part of the duplex link. Monitor the returned signal using headphones and verify the signal is being received. The signal should still sound like the transmitted signal but now may have noise and fading present. The SIGNAL PRESENCE light on the modem will indicate the general quality of the receive signal. If the light is on 2/3 of the time or more, usable data should be able to be exchanged over the circuit. Check the INPUT OFFSET and insure the display is reading 75 Hz or less. Ideally the offset should be 3 Hz or less. If the offset is greater than 3 Hz, make sure the FREQUENCY CORRECTION A and B is ON.

1-4 HF LOOPBACK – Verify that the crypto KG-36 can synchronize. Synchronization times may be longer than normally expected due to circuit delays and fading. See next section for some measured synchronization times. It may be necessary to attempt synchronization several times if the hf circuit is of marginal quality.

After synchronization, message transmission on the loopback circuit may be attempted. The loopback circuit will show the accumulate effect of fading and noise resulting from the signal going both ways on the duplex link. The loopback thus will indicate "worst-case" conditions on the link at the time, and actual operation should proceed with less difficulty.

CIRCUIT OPERATION

Successful completion of the 4 loopback tests means that the circuit is ready for data transmission. If, at this time, the KG-13 crypto sets have not been included in the loopback test procedures, loopback test 4 should be performed with the crypto sets in the circuit. Synchronization times will usually be on the order of a few seconds for a normal hf circuit. Sometimes, however, hf propagation conditions are such that several attempts at synchronization may be required.

The AN/TYC-5A contains a selectable transmission line-delay switch which permits synchronization to be achieved even though lengthy transmission delay times may be present on the circuit path. Such delays would generally be present when the modems were operated in the coded position or over satellite circuits. The line-delay switch is variable and can be set for delays (seconds) or 0.1, 0.6, 1.1, 1.6, 2.1, and 2.6. Synchronization times with this line-delay switch in the circuit and with operation in an rf loop are shown in table 6.

At no time could synchronization be achieved in loopback with the line-delay switch set in the 0.1-second position, and at no time should the unit be operated with the switch in this position. The long synchronization times at the lower data rates in the half-rate coded position are another reason why the low data rates are not recommended rates in tables 1 and 2. Any loss of crypto synchronization due to interference or fading would mean much time would be lost in the resynchronization procedure.

TABLE 6. SYNCHRONIZATION TIMES IN RF LOOPBACK OPERATION.

Modem Data Rate	Synchronization Time With KG-13 in MODE 32 (Seconds)	Minimum Line-Delay Switch Position That Sync Will Occur (Seconds)
2400 Coded	10	0.6
1200 Coded	10	0.6
600 Coded	15	0.6
300 Coded	25	0.6
150 Coded	55	1.6
75 Coded	100	1.6

The AN/TYC-5A and the AUTODIN Switching Centers (ASC) are equipped with Crypto Ancilliary Units (CAU) which are designed into the AUTODIN procedure to provide 3 automatic attempts at resynchronization of a circuit that has lost synchronization. If the termination involves an ASC at one end of the circuit, 3 failures at resynchronization will automatically take the data user off-line. If the synchronization failure occurs during message transfer, an alarm will sound in the ASC and the ASC technical controller will initiate action to bring up the circuit. If the loss of synchronization occurs at any other time, the ASC technical controller will not make an effort to re-establish the circuit until either a message comes through AUTODIN to be sent to the remote AN/TYC-5A or until the controller is informed by the remote AN/TYC-5A operator that the circuit is to be restarted.

CIRCUIT ORDERWIRE CONTROL

Orderwire control of the AUTODIN circuit over hf is essential. The orderwire is used to coordinate start-of-service, frequency changes, and other controls needed for AUTODIN operation. It is essential for locating problem areas in the AUTODIN link and for isolating at which ends of the link any problems occur. Frequency changes cannot be coordinated quickly and accurately without a reliable orderwire capability. AUTOVON, if available, is the best method for providing orderwire circuit control and coordination.

If no wire-line coordination channels are available, then radio-channel coordination must be established. Radio circuit orderwire can be time-shared with the AUTODIN data channel, be on the opposite sideband of the data channel, or use independent radios and hf frequencies.

TIME-SHARED ORDERWIRE

Most channel control is needed at times when no AUTODIN traffic is being passed, and consequently time-sharing of the data channel may be acceptable procedure. This procedure will be used in the absence of AUTOVON, 6-kHz assignments, or when limited

amounts of hf radio equipment are available. To initiate service, a 2-way link would be established on one of the assigned frequencies. This link would most likely be voice, although TTY could be used. After the link has been established and other assigned frequencies have been checked as being reasonably clear of interference, one end of the link then changes frequency to the A frequency and a full-duplex voice is attempted. If successful, the channel can be changed over to AUTODIN service. If not, then an additional frequency change must be attempted, probably coordinated by meeting back on the original frequency.

NOTE

In checking frequencies with the R-1051 receivers for occupancy prior to use, keep in mind that the AGC in the receiver will bring up the level of weak signals to produce a constant level audio output. Often, especially on shorter hf circuits, the desired signal will override almost any other signals that can be heard on the frequency. Thus, if it appears that a frequency is occupied, it is still often possible to use that frequency.

OPPOSITE SIDEBAND

If 6-kHz frequency assignments are available, it is possible to use the non-data sideband for orderwire communications. Often, for a 6-kHz double sideband, one of the sidebands will have some level of interference. The data link should be put on the clearest sideband and the other used for the orderwire communications. Thus, poor orderwire copy would not necessarily mean that the data communications link was poor. Radio operations should check with the data users on the AN/TYC-5A before requesting frequency changes, to determine if propagation problems or interference problems represent the source of poor communications.

INDEPENDENT RADIOS AND FREQUENCIES

If sufficient hf radios are available, the orderwire can be maintained on frequencies apart from the data link. The orderwire frequency would also provide a backup to the AUTODIN data link; if problems were encountered on the data circuit, this circuit could be changed over to use the orderwire frequency while the orderwire operator searched for a new frequency.

DATA OPERATION

After completion of loopback tests and verification that crypto synchronization can be established, data operation can begin. The AN/TYC-5 will be operated in the same manner as in the normal wire-line circuit. In most cases, the operator will note that the circuit seems to be of quality poorer than that experienced in the wire-line case. Poorer quality will often be indicated by the SYNC light on the receiver portion of the AIU panel of the AN/TYC-5A.

This light provides the AN/TYC-5A operator with a good indication of circuit quality. Normally the light will be steady during wire-line operation, but some occasional flashes of the light will be encountered even on a good quality hf circuit. Increased flashing of the light indicates deteriorating quality of the received signal. If the SYNC light is on less than 50 percent of the time, probably AUTODIN traffic cannot be passed. If this is the case, the hf receiver and the receive portion of the MX-513 modem should be checked for proper tuning and, if tuning is found to be proper, a new transmit frequency must be found for the remote end of the circuit.

It may be found that no data transfer is taking place even though the SYNC light indicates a good quality receive circuit. The problem is then likely to be on the transmit portion of the duplex link; the remote end of the link is not properly receiving the local transmit signal. On the AIU panel, this situation would be indicated by a large number of NO ANS or BAD ANS lights on the transmitter portion of the AIU.

Operation over an hf link in no way affects the selected language media format (LMF). Data transfer will occur at a rate dependent upon the quality of the hf channel and not upon the input/output peripherals. One warning, however, concerns the length of messages. The hf channel noise will, on occasion, produce a noise burst which the AN/TYC-5A will interpret as the Reject Message (RM) symbol. Thus, a message in the process of transmission will be rejected and will have to be sent again. For messages longer than about 100 or 200 line blocks and noisy channel conditions, the RM becomes an annoyance and can reduce throughputs. For this reason, message lengths longer than about 200 line blocks are not recommended on HF AUTODIN.

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APPENDIX A

SLOPING-VEE ANTENNA

The Sloping-Vee is an excellent antenna for tactical use. It is relatively simple to transport and install. Only one mast is required, and it needs only to be strong enough to support the 2 legs of the antenna. The antenna-coupler system of the AN/TSC-15 can effectively match this antenna at any frequency greater than 4 MHz.

The antenna can be configured in 2 ways. One configuration, illustrated in figure A1, uses coaxial transmission line and a balun. The balun, an rf transformer for matching the 600-ohm impedance of the antenna to the 50-ohm transmission line, is mounted on the mast at 60 ±3 feet (18 ± 0.9 metres) above the ground. RG-8U coaxial cable or equivalent is used and should be sufficiently long to reach between the balun and the AN/TSC-60/TSC-15.

The antenna proper consists of 600 feet (183 metres) of number 10 copper clad or, preferably, 3-strand, number 16 or larger copper-clad wire. Insulators sufficient to hold the antenna would probably be one inch (2.54 cm) by 4 inches (10.16 cm) in size.

Parameters of the antenna are shown in table A1.

The second configuration of the antenna is shown in figure A2. This configuration uses 600-ohm open transmission line and 370-ohm terminating resistors. If it is possible to obtain the terminating resistors, their use will improve the gain of the antenna by about 2 dB and improve loading characteristics slightly. The open feedline is an alternative; it will permit the balun to be placed anywhere.

TABLE A1. SLOPING-VEE ANTENNA PARAMETERS

Path Length (Miles)	Leg Length (Metres)	Angle α (Degrees)	Optimum Freq Range
400-750	80	25	4-20 MHz
750-1000	100	25	4-25 MHz
1000-1500	80	25	5-30 MHz
1500-2000	100	20	5-30 MHz
2000	100	20	6-30 MHz
All Range compromise	100	20	

Note: Height of all of above is 60 feet.

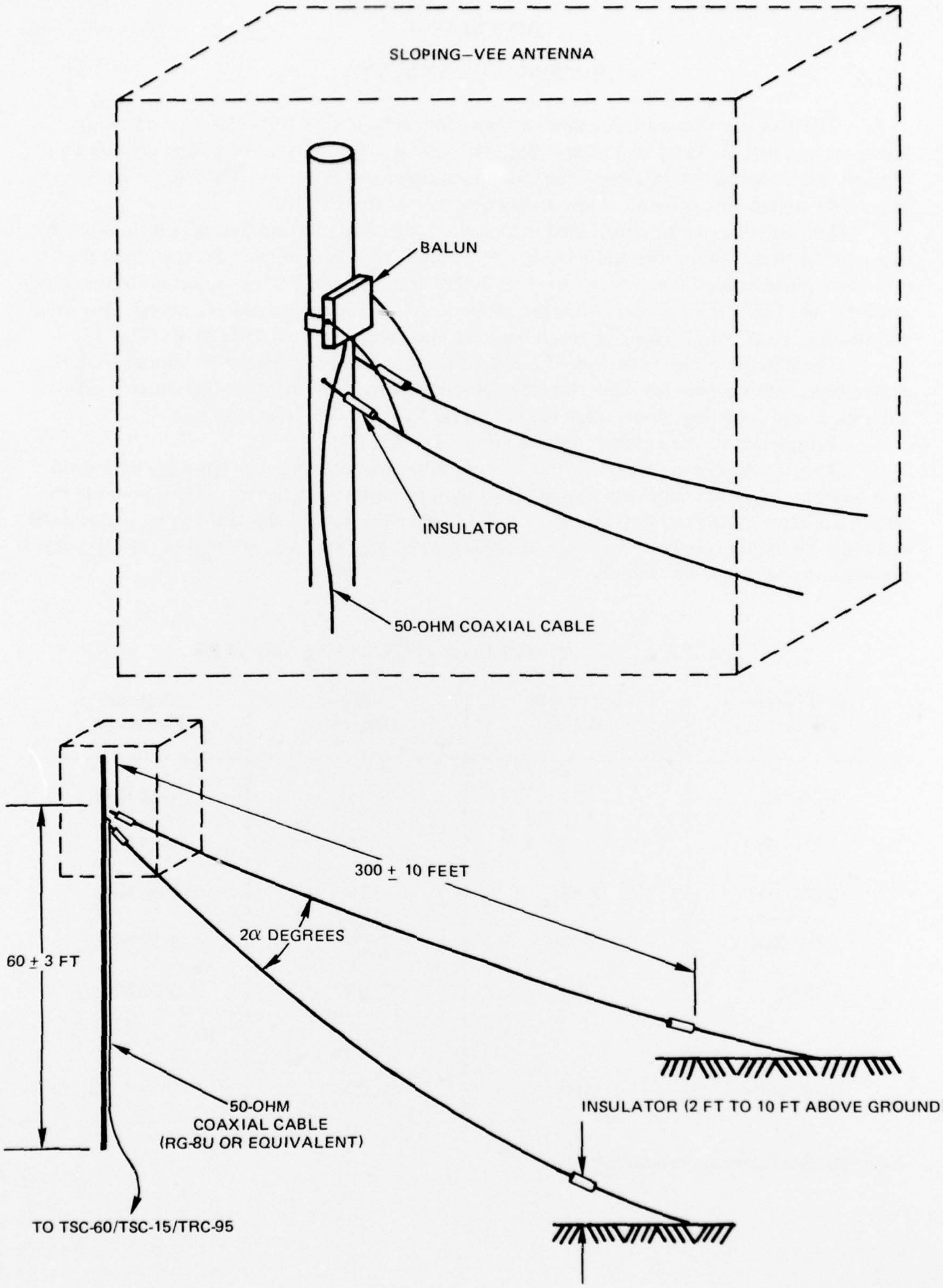

Figure A1. Coaxial-fed Sloping-Vee antenna.

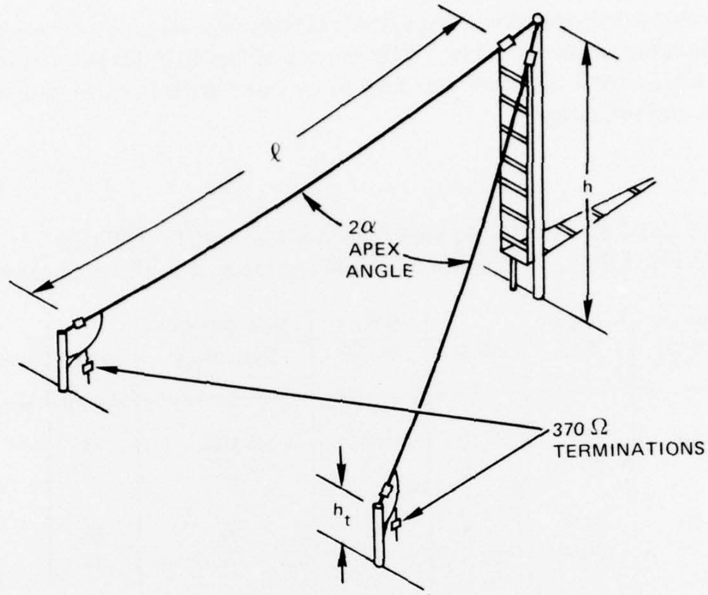

Figure A2. Geometry of Sloping-Vee antenna.

APPENDIX B

SYSTEM PERFORMANCE PREDICTIONS

Tables in this appendix contain predicted efficiencies for an HF AUTODIN circuit operated under a wide range of conditions. Interpolation between months, sunspot numbers, and local time on any table or between tables, will give an estimate of the predicted MUF and most reliable frequency.

Signal-to-noise levels and predicted system efficiencies are also available from the tables or by interpolation between tables. Efficiencies of less than 90 percent indicate conditions under which particular care will have to be taken with frequency management and circuit installation and operation.

TABLE B1. SYSTEM PERFORMANCE PREDICTIONS
(SHORT PATH, TROPICS 215 miles, dipole antennas, 0.3 kW transmit power)

Month	Sunspot Number	Local Time	MUF	S/N at MUF	Most Reliable Frequency	S/N	Predicted Efficiency
March	10	1200	7.8	65	6 MHz	75	.95
		0000	7.5	56	6	55	.30
June	10	1200	7.4	67	6	75	.95
		0000	4.5	53	4	54	.30
Sept.	10	1200	7.4	64	6	73	.95
		0000	6.2	56	4	53	.15
Dec.	10	1200	7.7	69	6	80	.95
		0000	4.5	62	3	62	.70
March	150	1200	12.5	56	6,7	72	.95
		0000	12.2	61	10	60	.60
June	150	1200	12.0	61	6,7,8	72	.95
		0000	10.4	62	8	60	.60
Sept.	150	1200	12.8	55	6,7	71	.95
		0000	12.4	65	10	63	.75
Dec.	150	1200	12.8	59	7	78	.95
		0000	9.9	67	7	65	.80

TABLE B2. SYSTEM PERFORMANCE PREDICTION
(LONG PATH, TROPICS, 2650 miles rhombic/sloping-vee antenna, 0.3 kW transmit power)

Month	Sunspot Number	Local Time	MUF	S/N at MUF	Most Reliable Frequency	S/N	Predicted Efficiency
March	10	1200	24.0	82	18	80	.95
		0000	15.5	80	12	71	.90
June	10	1200	21.0	81	15	81	.95
		0000	11.6	72	8	60	.60
Sept.	10	1200	23.7	81	15	72	.95
		0000	11.2	73	8	60	.60
Dec.	10	1200	24.9	80	15	75	.95
		0000	10.7	78	8	67	.85
March	150	1200	34.2	74	22	82	.95
		0000	35.9	78	18	87	.95
June	150	1200	31.3	85	18	80	.95
		0000	29.4	79	15	85	.95
Sept.	150	1200	35.4	66	22	82	.95
		0000	36.9	79	18	90	.95
Dec.	150	1200	35.0	62	22	86	.95
		0000	29.6	73	18	92	.95

TABLE B3. SYSTEM PERFORMANCE PREDICTION
(SHORT PATH, TEMPERATE, 230 miles dipole antennas, 0.3 kW transmit power)

Month	Sunspot Number	Local Time	MUF	S/N at MUF	Most Reliable Frequency	S/N	Predicted Efficiency
March	10	1200	9.5	75	6,7	82	.95
		0000	4.6	59	3	61	.65
June	10	1200	6.7	73	4	72	.95
		0000	6.2	58	4	58	.50
Sept.	10	1200	7.6	75	6	80	.95
		0000	4.7	60	3	61	.65
Dec.	10	1200	8.4	77	6	83	.95
		0000	2.9	62	3	62	.70
March	150	1200	15.4	72	7,8	79	.95
		0000	10.1	66	7	64	.80
June	150	1200	10.7	69	8	75	.95
		0000	10.3	63	8	62	.70
Sept.	150	1200	13.5	70	8	77	.95
		0000	9.9	67	7	65	.80
Dec.	150	1200	13.8	70	6	80	.95
		0000	5.8	62	4	64	.80

TABLE B4. SYSTEM PERFORMANCE PREDICTION
LONG PATH, TEMPERATE, 2900 miles rhombic/sloping-vee antenna,
0.3 kW transmit power)

Month	Sunspot Number	Local Time	MUF	S/N at MUF	Most Reliable Frequency	S/N	Predicted Efficiency
March	10	1200	26.2	88	18	84	.95
		0000	10.2	74	8	64	.80
June	10	1200	21.2	86	15	77	.95
		0000	11.8	76	10	70	.90
Sept.	10	1200	20.5	87	15	80	.95
		0000	9.7	74	8	66	.85
Dec.	10	1200	22.9	90	18	82	.95
		0000	8.4	70	7	64	.80
March	150	1200	45.7	54	26	88	.95
		0000	22.7	86	12	80	.95
June	150	1200	31.4	80	18	80	.95
		0000	23.5	81	15	87	.95
Sept.	150	1200	40.3	72	26	88	.95
		0000	22.7	86	12	82	.95
Dec.	150	1200	39.9	64	26	90	.95
		0000	17.1	93	10	77	.95

TABLE B5. SYSTEM PERFORMANCE PREDICTION
(INTERMEDIATE PATH, 1300 miles, rhombic/sloping-vee antenna,
0.3 kW transmit power)

Month	Sunspot Number	Local Time	MUF	S/N at MUF	Most Reliable Frequency	S/N	Predicted Efficiency
March	75	1200	27.8	69	18	96	.95
		0000	17.5	99	12	90	.95
June	75	1200	19.3	90	18	96	.95
		0000	18.4	96	12	89	.95
Sept.	75	1200	23.6	84	18	96	.95
		0000	16.4	100	12	89	.95
Dec.	75	1200	27.9	83	22	98	.95
		0000	12.9	96	10	78	.95

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